NUTRIENT CYCLES IN FOREST PLANTATIONS, THEIR CHANGE WITH AGE AND THE CONSEQUENCE FOR FERTILIZER PRACTICE

Hugh G. Miller
The Macaulay Institute for Soil Research, Craigiebuckler,
Aberdeen, AB9 2QJ, Scotland

ABSTRACT

The twentieth century has seen a great expansion in the use of fertilizers in forestry, a development seemingly at variance with the nineteenth century concept that forests are self-maintaining and even capable of improving soil fertility. However, when these early ideas are examined in the light of recent information on the input and cycling of nutrients, it is shown that in closed-canopy forests nutrient demands on the soil are low both because of pronounced recycling within the tree and within the ecosystem, and because of efficient capture and retention of atmospheric nutrients, although nitrogen immobilization in the humus can lead to late rotation nitrogen immobilization in the humus can lead to late rotation nitrogen deficiency. By contrast, a newly planted forest has a high nutrient demand both because the developing foliage biomass and nutrient cycles have to be charged with nutrients, and because the capture and retention of atmospheric nutrients is low. It is suggested therefore, that the recent rapid increase in the use of fertilizers in forests mainly reflects the great expansion of afforestation, and that after canopy closure the nineteenth century concept of self maintaining cycles is essentially correct, provided that the canopy remains undamaged.

INTRODUCTION

"Almost any soil can furnish a sufficient quantity of mineral substances for the production of trees" (Schlich, 1904). Thus Schlich taught the students of his generation the conventional wisdom of the nineteenth century. Seventy five years later Pritchett (1979) was to point out to the students of our generation that the "correction of nurtient deficiencies is common practice in pine forests of southern United States, in coniferous forests of the Pacific Northwest, central Europe and Scandinavia, and in exotic forests of Australia-New Zealand, South America and southern Africa". During the period that separates these two statements occurred the greatest expansion of afforestation in history.

One can detect among today's managers a slight sense of grievance that acceptance of the use of fertilizers should have come so slowly, despite the clear benefit they can bring, the blame seemingly being placed on those like Schlich who laid the foundation of our modern silviculture. So one can find, and sympathise with, statements such as "a great hindrance to a speedier development of forest fertilization was its sentimental rejection" (Baule and

and Fricker, 1970), or from John Davies (1979), undoubtedly the greatest proponent of the use of fertilizers in British forest management,, "One is acutely aware that although the science of forestry is still in its infancy, it is somewhat handicapped by tradition. Perhaps some of the reasons for this can be found in the academic background of university lecturers in Europe ... it has taken British foresters a very long time to realise the dominion they have over their sites using techniques developed from agricultural practice. My outlook, therefore, is that of the tree farmer".

It is hoped in this paper to rehabilitate the teachings of Schlich and his generation without denying the tenets of the tree farmer, for it is contented that there is no disparity. That the differences, apparently so fundamental, arise in considerable measure from the great increase in afforestation during this century. That consideration of nutrient cycles, and their change with development of the stand, lead to the conclusion that while the agricultural analogy espoused by Davies is relevant prior to canopy closure, thereafter the nineteenth century concepts remain remarkably apposite. These concepts, and their recent elaboration will be considered in relation to a forest of 10 to 12 m height and then contrasted to the situation as trees grow from 0.5 to 2.5 m. There follows a discussion of the very similar concepts recently put forward separately by Attiwill (1979) and by Miller (in press).

NUTRIENT CYCLING AFTER CANOPY CLOSURE

Ideas on forest nutrition during the late nineteenth century, although rooted in traditional European forestry, had been developed and quantified by the impressive investigations of Ebermayer (1882) as a result of which Schlich (1904) was able to enunciate the following five points.

(i) The substances (i.e. nutrients) required by forest trees are, qualitatively, the same as those required by field crops.

(ii) Beech high forest requires for the production of leaves and wood nearly as much mineral substances as an average field crop ...

(iii) Conifers require smaller quantities ...

(iv) For the production of wood alone (excluding the leaves) forest trees require much smaller quantities than field crops ... on average about one twelfth of the quantity ...

(v) Almost any soil can furnish a sufficient quantity of mineral substances for the production of a crop of trees, provided the leaf mould (humus) is not removed ... If however, the removal of litter is carried on annually and for a long period, any but really fertile soils are likely to become exhausted, just as lands on which field crops are grown cannot as a rule go on for ever without manuring".

The first four points encompass the concept that nutrient uptake by forests is qualitatively and quantitatively similar to that of other plant crops, but that the amount accumulated in timber is only a small proportion of the uptake. the fifth point then implies essentially two further concepts. First, that inputs to the pool of available soil nutrients must be at least equivalent to the rate at which these nutrients are immobilised in new tree tissues and accumulating humus, otherwise tree growth would decline. The source of these inputs was not elaborated although Schlich does state, presumably on the basis of work by Schloesing (1890), that humus may "absorb from the atmosphere considerable quantities of ... ammonia", and he was undoubtedly familiar with the idea that rain contains nitrogen, for the importance of this imput to agricultural crops had been the subject of controversy for some time (Liebig 1885; Russell and Richards 1919). The second, and more directly stated, concept in point 5 is that a large portion of the uptake is returned to the soil in litter and that, if this cycle is prevented, the unspecified inputs would be insufficient to maintain the fertility of the site.

It will be suggested in the following discussion that recent research has not repudiated any of these three concepts, but rather, has elaborated and strengthened them within the context in which they were proposed, i.e. the closed-canopy forest.

Nutrient Uptake and Accumulation

Rates of uptake of major nutrients by managed forests are broadly comparable to those measured for other vegetation types at the same general latitude (Table 1), coniferous forests, as Schlich suggested, being rather less demanding than deciduous woodland. However, in trees only about a quarter to a third of the uptake accumulates in new tree tissues, remainder being released in litter fall and crown leaching (Table 2).

TABLE 1. Rates of Uptake Measured in 11 m Tall Closed-canopy Corsican Pine (Miller et al., 1979) in Comparison to Published Values of Utpake by other Crops in Britain (Frissel 1977).

Community	Rate of Uptake (kg ha^{-1} yr^{-1})		
	N	P	K
Corsican pine plantation	69	6.0	28
Heather moorland	42	3.6	11
Unimproved grassland	44	3.8	25
Improved grassland	105	10.5	77
Grass-clover mixture	184	20.1	144
Winter wheat	95	21.2	147
Mixed deciduous woodland	167	10.8	77

Thus Schlich's contentions regarding the uptake and accumulation by trees relative to other crops are essentially correct. Although there remains the problem of explaining how some tree species, in particular the evergreen coniferous species, are able to achieve rates of net primary production equivalent to the best of agricultural crops, despite nutrient uptake rates comparable to poor, low productivity, agricultural systems. For example, the measured uptake in Table 2 is associated with a net primary production of 19 t ha^{-1} yr^{-1}, and this same stand briefly achieved a growth rate 25 t ha^{-1} yr^{-1} (Miller and Miller 1976). which many regard as close to the theoretical maximum for plant production at the latitude of northern Scotland. The explanation probably lies in the efficiency with which trees conserve and reuse nutrients. Calculations (Table 3, Figure 1) for the Corsican pine (Pinus nigra var. maritima (Ait.) Melv.) referred to in Tables 1 and 2 show that root uptake supplies only a half or less of the nutrients required for new growth, the remainder being recovered from older tissues as they age and die. The main source is the dying needles, although limited amounts do come from other tissues. Certainly nutrients are recovered during heartwood formation (Merril and Cowling 1966), to the extent that in certain eucalypts there can be an almost forty-fold drop in phosphorus concentrations (Crane 1978), but in absolute terms the amount that can be recovered from stem wood is probably fairly low.

TABLE 2. Rates of Transfer, Accumulation and Release of Nutrients in a Stand of Fast Growing Corsican Pine in North Scotland (Miller et al., 1979).

Process	Rate of Process (kg ha^{-1} yr^{-1})				
	N	P	K	Ca	Mg
Uptake	69	6.0	28	34	10.9
Accumulation in trees	18	2.1	11	12	3.6
Release:					
litter fall	51	3.9	11	21	4.3
crown leaching	trace	trace	6	1	3.0
Accumulation in humus	12	1.5	1	5	1.6

In high latitudes, tree growth is seasonal and seldom coincides with the period of pronounced leaf fall. The recovered nutrients therefore, together with those taken up by the roots outwith the immediate growing season, have to be temporarily stored pending the resumption of growth, the site of this storage being largely in twigs, roots and, except in deciduous species, the remaining foliage. Under normal conditions this temporary seasonal storage plus root uptake during the growing season, which Miller et al. (1979) termed "first-levels" sources of nutrients, are sufficient to maintain growth. Exceptionally, however, a tree has to draw on "second-level" sources represented by potentially mobile forms in the tree tissues that can be used to make up, at least in part, for an inadequate supply from first-level sources. This can be mobilization of reserves previously accumulated when supply exceeded demand for growth, as can happen following fertilizer application (Miller et al. 1976). More

usually, however, such mobilization occurs at a suboptimum level of nutrition and is at the expense of the proper functioning, or even continued existence, of older tree tissues - hence the increased needle fall associated with the onset of nitrogen deficiency (Turner 1977).

Thus whereas, Schlich's contention that nutrient uptake by trees is broadly comparable to other vegetation types remains true, enough is now known about the internal cycle within the evergreen coniferous species to suggest that this is an efficient nutrient-conserving mechanism that enables high productivity on low fertility soils, The prerequisite, however, is that the trees must have first accumulated a sufficient nutrient capital.

TABLE 3. Comparison of Sinks and Sources of Nutrients for the Stand in Fast Growing Corsican Pine in North Scotland.

Nutrient flux	Rate of flux (kg ha^{-1} yr^{-1})		
	N	P	K
SINKS			
1. In new needles	92	9.4	45
2. To replace lost structural tissues	20	1.7	4
3. Net increase in structural tissues	26	3.0	13
4. Total requirements	138	14.1	62
SOURCES			
5. Uptake from soil	69	6.0	28
6. Recovery from needles before death	61	7.2	32
7. Necessary recover from other tissues	8	0.9	2
8. Total of all sources	138	14.1	62

Notes

Calculations and regressions are based on top-whorl foliar N of 2.01%, basal area increment of 2.09 m^2 ha^{-1} yr^{-1}, standing volume of 226 m^3 ha^{-1} and volume increment of 19.7 m^3 ha^{-1} yr^{-1}.

1. Calculated from an unpublished regression of weight of new foliage on basal area increment ($P<0.001$) and unpublished data on nutrient concentration.
2. From calculated total litter production, including an allowance for unmeasured root depth (Miller et al. 1979), minus needle fall calculated from an unpublished regression on basal area increment ($P<0.01$).
3. Increase taken as being proportional to relative volume increase.
4. 1 + 2 + 3.
5. From Miller et al. (1976).
6. Weight of nitrogen in new needles (see note 1) minus weight in needle fall using calculated weight of needle fall (see note 2) and nitrogen concentration from Miller et al (1976); for potassium crown leaching losses are also subtracted (Miller et al. (1979).
7. 4-(5 + 6).
8. 5 + 6 + 7.

Inputs to Pool of Available Soil Nutrients

Tree roots draw their nutrients from the soil solution and from exchange sites. If growth is to be sustained these available supplies in the soil must be continually replenished from other sources.

Within the soil, the weathering of soil minerals and the decomposition of organic matter are particularly important processes, but very difficult to measure. Various approaches, including instrumented catchments, have been used to estimate rates of mineral weathering in the field (Table 4), but as these techniques are dependent on careful correction for atmospheric inputs and changing biomass accumulation, precise and accurate assessments of weathering rates from field studies are unlikely. On the other hand, laboratory studies usually exclude many of the factors that may promote weathering reactions, including the presence of active tree roots and mycorrhizal fungi, although definitive experimental support for enhanced weathering in the presence of mycorrhizas is still lacking (Bowen 1980). What is clear is that measurements of total and "available" (i.e. extractable or mineralizable under carefully controlled conditions) forms of an element given little insight into the dynamics of conversion of one form to another. As the important factor is the rate at which the available pool can be recharged from non-available sources, the simple comparison of tree accumulation with some measurement of soil availability is meaningless (Crane 1978), the more so because tree roots not only remove nutrients from the available pool but also through promoting weathering reactions, influence the rate of recharge.

TABLE 4. Estimates of Rates of Nutrient Release through Weathering of Soil Minerals obtained by Analysis of Outflow Waters. Values Published by Viro assume no Net Change in Biomass Accumulation Whereas those of Likens *et al.* include the Increased Accumulation in Living and Dead Biomass.

Source	Nutrient release (kg ha^{-1} yr^{-1})		
	K	Ca	Mg
Viro (1953)	4.0	12.0	4.0
Likens *et al.* (1977)	7.1	21.0	3.5

Perhaps the only certain measure of availability is tree uptake and, despite claims to the contrary, there is no positive evidence of a long-term decline in soil fertility as the result of tree growth and timber harvesting. In part this may be due to nutrient replenishment from the atmosphere for it has been shown that such inputs of potassium and magnesium (Table 5) to a stand of Corsican pine were almost sufficient to replace the amounts of these elements being immobilized in new tree tissues and accumulating humus. From Fig. 1 it can be seen, however, that the inputs of nitrogen and phosphorus from this source were not sufficient to compensate for the rates of immobilization, although at other sites (Table 5) much larger

nitrogen inputs have been recorded. The soil, therefore, always has to supply a significant proportion of the phosphorus and, to a lesser extent, nitrogen taken up by these trees.

It will be noted from Table 5 that for some elements the "aerosol" component of the atmospheric input can be relatively large. This term encompasses the material that is filtered from the atmosphere by becoming trapped on tree surfaces, but which is not adequately sampled in a normal rain gauge. Although conveniently termed "aerosol input" it certainly includes other components, including gases and fine rain drops and, as such, is more than the "dry deposition" of some studies (Miller and Miller 1980). Certainly the simple placing of a wire mesh over a rain gauge can lead to marked increases in the concentration of many elements in the collected water (Table 6) and it is presumed, although not yet established, that the magnitude of the input is in some considerable respect a function of the size and structure of the receiving vegetation. Thus, it is likely that this input, which Mayer and Ulrich (1974) have termed the "filtering effect" of vegetation, would be more pronounced in mature forests than in newly planted trees, scrub or grass. Indeed, work by Kellman (1979) has suggested that soil enrichment as a result of the filtering effect in savanna woodland is instrumental in allowing establishment of the more demanding rain forest species. Similarly, Miller et al. (1979) have postulated that enhanced input of atmospheric nutrients as a result of the filter effect, plus effective retention within the ecosystem, is the mechanism evolved by coniferous trees to enable them to thrive on soils low in potassium, magnesium and to a lesser extent, calcium and nitrogen.

TABLE 5. Inputs of Nutrients to Forests in Rainwater and from Other Atmopsheric Sources.

	Inputs (kg ha^{-1} yr^{-1})				
	Total N*	P	K	Ca	Mg
INPUT IN RAIN					
Measured at site of stand in Table 2[1]	4.8	0.04	2.8	2.9	2.6
Measured at six other sites in Scotland[2]	4.0–21.9	0.02–0.13	0.8–11.9	4.4–11.9	2.1–7.0
Other reports for Europe[3]	8.2–21.8	0.04–0.50	0.5–19.6	0.9–16.7	0.5–4.7
INPUT OTHER THAN RAIN					
Microbial fixation[4]	0.4–3.2				
Trapped aerosols and dust:					
For stand in Table 2[1]	trace	trace	6.9	3.5	2.1
Germany[5]	3.6	0.2	4.8	6.4	0.6

[1]Miller, Cooper and Miller (1976)
[2]Miller, Miller and Cooper (1980)
[3]Horntvedt (1975)
[4]Granhall and Lindberg (1978)
[5]Mayer and Ulrich (1974)
*Total N includes NH_4, NO_3 and organic N

TABLE 6. Ratios of the Concentrations of Elements in Water Collected Beneath a Cylinder of Polyethylene Coated Wire Mesh to the Concentrations in Water Collected in an Aerodynamically Shielded Gauge at Six Sites across Scotland (Miller and Miller 1980).

	Increased concentration in water collected beneath wire mesh					
	Kilmichael	leanachan	Strathyre	Kershope	Elibank	Fetteresso
P	2.5	1.0	2.0	2.0	2.0	1.2
K	4.7	2.0	1.3	3.9	2.6	5.2
Ca	1.9	2.0	1.4	2.9	2.4	2.6
Mg	4.7	4.1	2.2	5.5	4.4	4.9

From whatever source, nutrient are only of value if they are either taken up by the trees or retained within the ecosystem in a form potentially available for uptake. There is now a large body of evidence (reviewed by Miller, 1979) to show that forests, with their surface roots and dense weft or mycorrhizal hyphae, are remarkably effective at taking up any nutrient that may enter the soil solution. An extreme example comes from the forests of Venezuela where less than 0.1% of radioactive tracers of several nutrient elements applied to the surface leached through the root-organic mat (Stark and Jordan 1978). Given the opportunity, as when fertilizers are applied, trees will even accumulate nutrients in considerably greater quantities than are required for immediate growth. This is not luxury uptake, as understood by physiologists working with annual plants, but, as mentioned earlier, is storage against future requirements. This, Miller *et al.* (1976) showed that for Corsican pine the longevity of the growth response to nitrogen fertilizer could be explained in terms of remobilization of nitrogen taken up and stored during the period of fertilizer application (mobilization from second-level sources).

Inputs from the atmosphere, therefore, are effectively retained within closed canopy forests and can replace all, or a large fraction, of the nutrients being immobilized in living and dead biomass. Indeed, comparison of Tables 5 and 7 suggests that such inputs are sufficient to compensate for harvesting losses of all nutrients other than phosphorus; even nitrogen would be adequately replaced except at extreme rates of exploitation. As there is then a further input to the available pool from the weathering of soil minerals and decomposition of soil minerals and decomposition of soil organic matter, there does not seem to be any difficulty in coping with the rather low demands for available soil nutrients made by a closed-canopy forest. Recent evidence thus supports the implication in Schlich's fifth point that there are inputs to the available nutrient pool at least comparable with the rate of immobilization, even though we now know that his suggestion of ammonia adsorption by humus is not an important process.

TABLE 7. Nutrient Content, Averaged per ha per year, of Harvested Material calculated for Slow - and Fast-growing Corsican Pine on Harvesting Policies of (A) Removing only Stem Wood and Stem Bark at Both Thinnings and Clear-felling over the Economic Rotation (70 Years and 60 Years, respectively) and (B) no thinnings and all above-ground components harvested when height reaches 12.5 m (45 Years and 25 Years, respectively) (Miller et al. 1980).

Growth rate in $m^3\ ha^{-1}\ year^{-1}$ maximum M.A.I.	Harvesting Policy	kg ha^{-1} $year^{-1}$ removed				
		N	P	K	Ca	Mg
6	A	1.6	0.17	1.0		
	B	3.4	0.42	2.2	3.3	0.70
16	A	6.4	0.58	2.9	4.2	1.18
	B	13.5	1.24	6.6	6.6	1.74

Interruption of the Cycle Through Removal of Litter

Schlich's reference to the removal of humus is based on Ebermayer's (1882) demonstration that the litter harvesting practised by Bavarian farmers was leading, on poor sites, to the development of nitrogen deficiency. Although such removal is not part of any current silvicultural practice there is the analogue that immobilization of nitrogen in humus can so restrict the cycle of this element that, on poor sites, a late rotation nitrogen deficiency may develop Taamm et al. 1960; Weetman 1962). Precisely this had occurred in the Corsican pine stand, referred to in Table 2, Miller and Cooper 1973), which was growing on coastal sand dunes with very low nitrogen capital. It is perhaps surprising that a deficiency of phosphorus is not also involved, but reports of a phosphorus deficiency at this stage are very unusual, possibly reflecting the efficiency with which mycorrhizas can extract phosphorus from lower horizons.

NUTRIENT CYCLING BEFORE CANOPY CLOSURE

The typical case of the tall post-canopy closure stand (Fig. 1) is thus one where nutrient demands on the soil are low because of efficient cycling within both the tree and the ecosystem, and where nutrient inputs are high because the full occupancy of the site by the trees and their roots provides an efficient mechanism for the capture and retention of atmopsheric nutrients. By contrast, the short pre-canopy closure stand has a high nutrient demand because of reduced opportunity for closed nutrient cycles, low inputs because only a small surface area is exposed to trap "aerosol" from the atmosphere and, so far as the trees are concerned, low retention of inputs as, at least initially, much of the site is occupied by weed species.

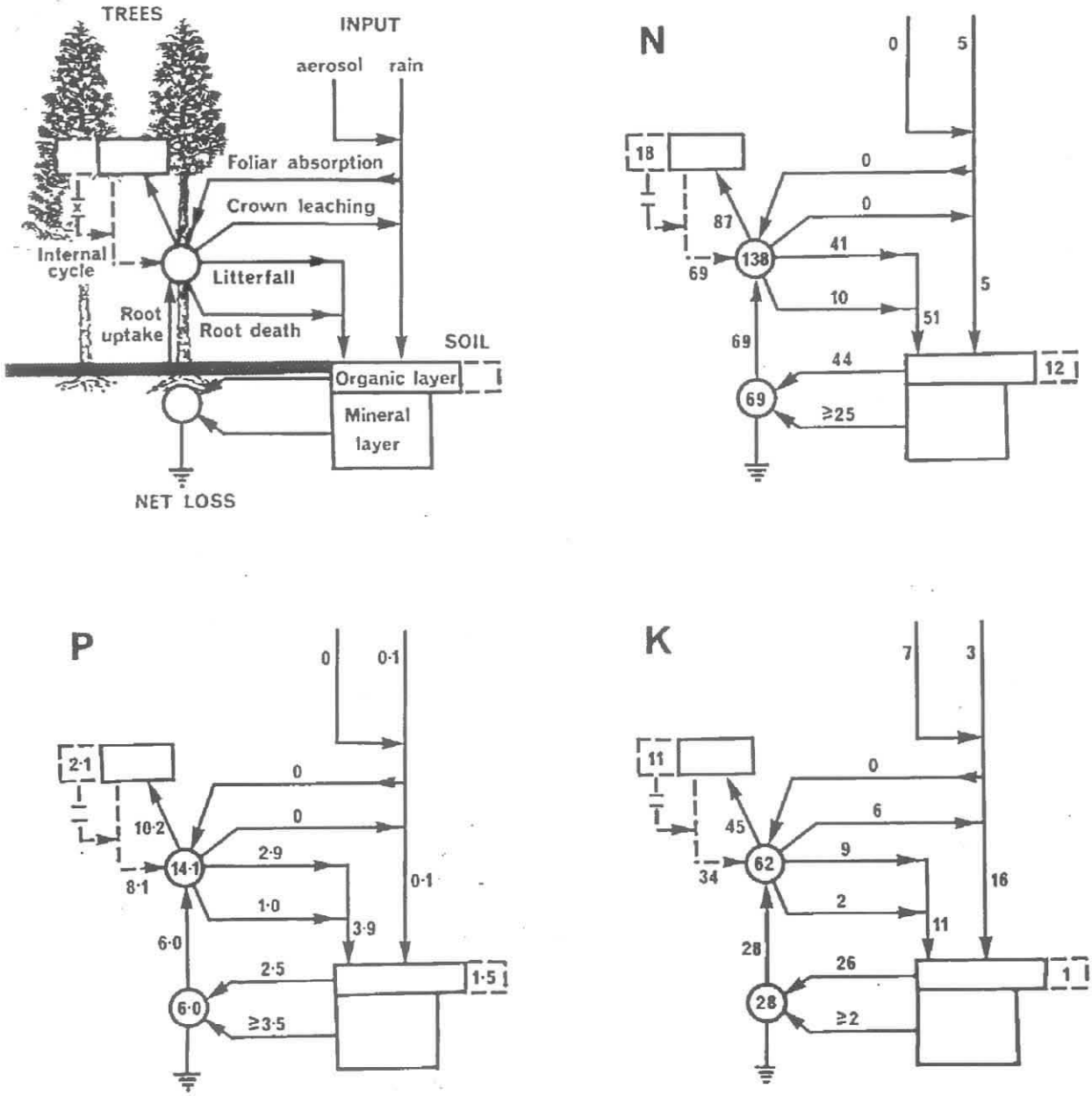

FIGURE 1. Annual Fluxes and Rates of Accumulation of Nitrogen, Phosphorus and Potassium Calculated as being Necessary to Sustain Rapid Growth of Corsican Pine, together with Measured Rates of Input. Zones of Accumulation are Shown by Rectangles, the Annual Rate of New Accumulation being Represented By the Dashed Portion. Mobile Pools in the Soil and the Tree are Depicted as Circles and Remobilization within the Tree by Dashed Arrows, Loop x being Mobilization from Second-level Sources (see Text). Value for Cycling within the Tree from Table 3; all other Values from Miller et al. (1979).

Some small trees are building their leaf area and each year the weight of new foliage considerably exceeds the weight formed a few years earlier (or for deciduous species, in the previous years) and is now being discarded. Thus a much retarded fraction of the nutrient requirements can be met by retranslocation from older tissues than is the case for the closed-canopy stand in Table 3. Similarly, annual nutrient release in litter fall, and hence cycling with the ecosystem, is a function of the tree's size a year or more previously (Fig. 2). During this time, therefore the tree has to find sufficient nutrients both to stock its rapidly expanding foliage biomass and to establish adequate cycling within the ecosystem. This is the period when the rate of accumulation of soil nutrients by the trees (Madwick et al. 1977) and humus is at its most rapid. it follows that during this development stage the concentration of available soil nutrients, and the severity of competition for these nutrients with weed species, are the critical factors controlling rate of crown development.

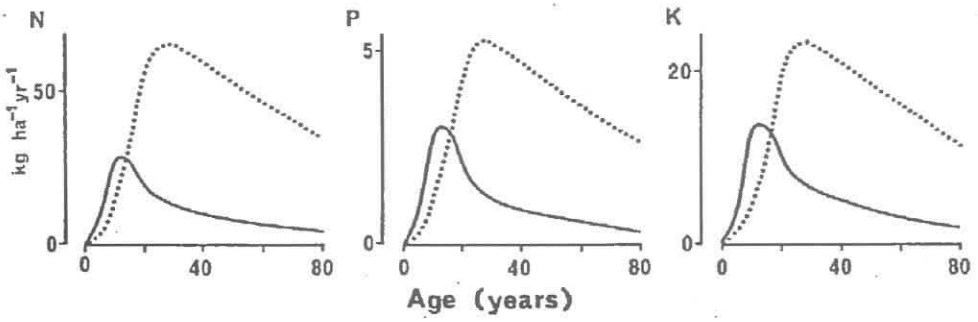

FIGURE 2. Calculated Rates of the Net Immobilization of Nutrients in Tree tissues (——) and the Further Amounts Taken Up and Released Through Litterfall, Root Death and Crown Leaching (...). Calculations are for the Same Stand of Corsican Pine Illustrated in Fig. 1 (Miller, in press).

CONSEQUENCES FOR FOREST FERTILIZATION

Consideration of the variations with tree age in the patterns of nutrient uptake, cycling and immobilization, as outlined above, lead Miller (in press) to suggest three distinct nutritional stages in the life of a forest stand. During the years prior to canopy closure (Stage I), tree growth is very dependent on the availability of soil nutrients. This is a stage when response both to application of a number of fertilizer nutrients and to a reduction in weed competition can reasonably be expected. In short, this is a stage when aspects of the cultivation, weeding and fertilization practices developed in agriculture can be of benefit to the forester. It is therefore not surprising that the forester's marked preoccupation with afforestation during the 75 years that have separated the textbooks of Schlich and Pritchett should be characterised by an increasing interest in the use of fertilizers.

Once canopy has closed, however, the reduction in rate of accumulation of nutrients associated with achievement of maximum foliage biomass, the establishment of the relevent nutrient cycles and the efficient capture and retention of atmospheric nutrients means that at this stage, Stage II, the demands made on the soil nutrient capital may be so low that supplies are rarely inadequate and fertilizer responses are unlikely. However, continuing immobilization of nitrogen in the humus during this period may eventually lead, on sites with low nitrogen capital, to late rotation nitrogen deficiency and progressive site deterioration (Stage III). Such a deficiency is common in the older coniferous forests of western North America and northern Europe, areas that were not the subject of intensive forest management during the nineteenth century.

An essential difference between Stages I and II is the amount of nutrient needed to form the foliage biomass. A reduction in foliage during Stage II (or subsequently) is equivalent to a partial reversion to Stage I. It follows that a crop which fails to respond to any fertilizer prior to thinning would, immediately after the destruction of a portion of the canopy by thinning, respond to the nutrient originally found to be deficient in Stage I.

Attiwill (1979) has similarly suggested, from his studies of nutrient cycling in Eucalyptus obliqua L'Herit, that growth of a forest may be considered as a sequence of three definable stages which he summarised as: "(i) growth of photosynthetic display and of the metabolic transport system, (ii) development of the heartwood as a support structure system, and (iii) maintenance of the ecosystem through the production of litter". Stage (i) in this system is clearly the same as the Stage I proposed by Miller. Similarly the stages (ii) and II are at least initially the same, although Miller chooses to emphasise the establishment of cycles as nutrient conserving nechanisms, whereas Attiwill emphasises the role of heartwood formation as "a growth-regulating process related to development". This stage in his system has a well defined end at the point when mean annual increment exceeds current annual increment, whereas Miller suggests no such limit to Stage II. Indeed it seems likely that Miller's Stage III, which it should be recalled is not an inevitable event, is no more than a particular variant of Attiwill's stage (ii), and that the Stage (iii) as defined by Attiwill being by definition beyond the end of the economic rotation, is simply not included in Miller's system. The similarity between the two systems, however, is striking and both serve to emphasise the importance of making statements only within the context of the development stage of the stand.

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